



Original research article

The psychology of participation and interest in smart energy systems: Comparing the value-belief-norm theory and the value-identity-personal norm model



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ARTICLE INFO

Article history:

Received 28 January 2016

Received in revised form 24 August 2016

Accepted 30 August 2016

Available online 18 September 2016

Keywords:

Value-belief-norm theory

Value-identity-personal norm model

Smart energy systems

Normative considerations

ABSTRACT

Environmental problems can be reduced if people would participate in smart energy systems. Little is known about which factors motivate people to actually participate in smart energy systems. We tested the factors that influence individuals' interest and actual participation in smart energy systems. We compared the predictive power of the value-belief-norm theory with a novel model to explain pro-environmental actions: the value-identity-personal norm model. Both focus on normative considerations in explaining behaviour, but the VIP model focuses on general rather than behaviour-specific antecedents. Our results show that both models explained a similar amount of variance in interest and actual participation in smart energy systems. This suggests that the value-identity-personal norm model is a promising model to explain and promote pro-environmental actions such as participation in smart grids. Further, it is more parsimonious than the value-belief-norm theory and focuses on general factors that are likely to predict other environmental behaviours as well. The value-identity-personal norm model is therefore a particularly promising model in promoting a range of environmental behaviours.

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1. Introduction

Environmental problems are among the biggest challenges we are currently facing. Global warming is a growing issue, as the world population increases, as well as fossil energy consumption per capita [13]. In Europe, households are responsible for 27% of the total energy consumption and 30% of the total electricity consumption [5]. Smart grids can potentially contribute to reduce environmental problems by enabling households to balance supply and demand of energy, save energy and increase energy efficiency [12,3,18]. In the current project, a smart energy system is an energy system in which renewable energy production, smart meters, and smart plug devices are integrated and coordinated through energy services, active users and enabling technologies. Smart energy systems often involve a decentralized production of renewable energy, for example the adoption of solar panels by households. Decentralized production of renewable energy can lead to uneven supply of energy (for example, more energy is available when the sun is shining) which requires supplement from fossil fuels. However, if

households change their energy demand to match supply of energy, efficient use of renewables can be increased and reliance on fossil fuels can be reduced. This can be realized by switching one's energy consumption to times when renewable energy is widely available (e.g., when the sun is shining; [19]). That way, smart energy systems can reduce the use of fossil fuels, thereby contributing to the reduction of environmental problems. Smart energy systems can only realize their true potential if households are willing to actively participate in such systems. Individual behaviour is thus crucial in promoting a transition to smart energy systems [30,9,45,43,26]. What influences individuals' interest in and their actual participation in smart energy systems?

Studies have shown that people are not always primarily motivated by financial costs and benefits. For example, people are willing to pay extra for more sustainable sources of energy [44]. Indeed, normative considerations play a key role in explaining environmental behaviour, including sustainable energy use [34]. An important theory explaining environmental behaviour that focuses on normative considerations is the value-belief-norm (VBN) theory (see Fig. 1; [38,37]). VBN theory proposes that relatively stable and general factors, namely values and environmental concern, affect behaviour specific variables (i.e., problem awareness, outcome efficacy and personal norm), which in turn influence behaviour. According to the VBN theory, people are likely to engage in pro-

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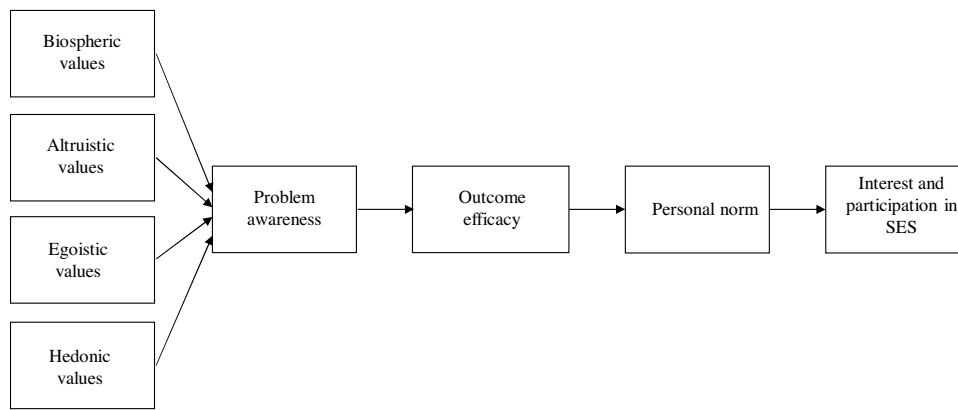


Fig. 1. The Value-Belief-Norm theory.

environmental behaviour when they feel morally obliged to do so. Feelings of moral obligation are stronger when people are aware of environmental problems caused by their behaviour (problem awareness), and when they feel they can do something about these problems (outcome efficacy). Problem awareness is higher, the higher one's environmental concern. Finally, environmental concern is influenced by people's values. Generally, strong biospheric values, reflecting that one strongly cares about nature and the environment, are positively related to environmental concern, and VBN variables further down the chain. Altruistic values, reflecting the extent to which people care about others, are also positively related to environmental concern and other VBN variables, but to a lesser extent. Egoistic values on the other hand, reflecting whether people care about money and power, are generally negatively related to environmental concern and the variables further down the chain. Hedonic values reflect to what extent people care about comfort and pleasure. Hedonic values have been found to be important predictors of environmental behaviour, however they have not been studied with regard to the VBN theory yet [35]. However, research has suggested that environmental concern could be excluded from the VBN theory, as values appeared to be a better predictor of VBN variables than environmental concern [32]. Therefore, we tested the VBN theory excluding environmental concern, resulting in a more parsimonious model without reducing the predictive power of the model much.

Research has shown that the VBN theory, or key variables from the VBN theory, predict a wide range of environmental behaviours and perceptions, including consumer behaviour and willingness to sacrifice (i.e., pay higher prices and reduce one's standard of living to protect the environment; [38]), the acceptability of energy policies [33], pro-environmental behaviours [25], recycling, refraining from driving, and environmental citizenship [27], ecological risk perception [31], the intention to use green devices [7], conservation behaviour [16], sustainable transport mode choice [14,22], and the adoption of alternative fuel vehicles [15]. However, VBN theory does not predict demonstrating for an environmental cause [38] and sustainability behaviours in an organization very well [2]. It has been suggested that the predictive power of the VBN theory is weaker when the behaviour is rather costly or effortful [37]. We will test if the VBN theory also explains behaviour in a new domain, namely participation in smart energy systems.

The VBN theory mainly includes behaviour-specific factors, notably problem awareness, outcome efficacy and personal norm. Behaviour specific predictors are believed to be strongly related to the relevant behaviour [1], which implies that the VBN theory may be strongly predictive of specific environmental behaviours. Yet, from a practical point of view, it would be advantageous to identify general antecedents of environmental actions, that are likely

to affect many environmental behaviours [39]. Targeting such general factors may increase the likelihood that people engage in many pro-environmental actions, which would have a more significant impact on environmental quality. Therefore, we propose a model focusing on general antecedents of environmental actions, namely the Value Identity Personal norm (VIP) model (see Fig. 2). Similar to the VBN theory, the VIP model proposes that environmental behaviour is influenced by feelings of moral obligation to engage in environmental behaviour (personal norms). The VIP model further proposes that personal norm is in turn influenced by one's environmental self-identity, which reflects the extent to which one sees oneself as a pro-environmental person [40]. Environmental self-identity is in turn influenced by biospheric values: stronger biospheric values result in a stronger environmental self-identity. The VIP model differs from the VBN theory in two important ways. First, the VIP model is more parsimonious than the VBN theory. Second, the VIP model focuses on general predictors of environmental actions, notably values and environmental self-identity, while personal norm is a behaviour specific variable. Previous studies provide empirical support for parts of the VIP model. More specifically, environmental self-identity has been found to mediate the relationship between biospheric values, and the intention to use green energy, energy behaviours, preferences for sustainable products, recycling, buying fair trade products and refraining from flying [8,40]. Furthermore, personal norm was found to mediate the relationship between environmental self-identity and the intention to use renewable energy as well as product preferences [41]. Recently, the VIP model has been found to predict environmental behaviour at work [28].

In the current study we aim to compare the predictive power of the VBN theory and the VIP model in explaining participation in a smart energy system. We will test to what extent the VIP model, focusing on general antecedents, is predictive of specific pro-environmental actions such as participation in smart grids, and how well the VIP model explains this behaviour compared to the VBN theory. We will include two indicators of participation in smart energy systems, interest in smart energy systems, and actual participation in smart energy systems. Interest in smart energy systems may not always translate into actual participation in smart energy systems, and may thus be related to different variables (cf. Refs. [24,29]). Therefore we also include, in contrast to most studies, whether people actually participate in the smart energy system project. We will test if the VBN theory, as it includes more behaviour specific variables than the VIP model, is more predictive of these different indicators of adoption of smart energy systems than the VIP model.

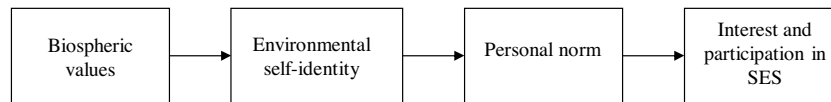


Fig. 2. The Value-Identity-Personal norm model.

2. Method

2.1. Participants and procedure

The study was part of a local project¹ that aimed to test smart energy systems. Participants of this study were sampled from 500 households equipped with rooftop solar panels in and around the neighbourhood Nieuwland in Amersfoort, a middle-sized city in the Netherlands. Participation was voluntary and participants were required to install smart meters that monitored their total gas and electricity use as well as the energy generated by their solar panels. In addition, they had to install several smart plugs that would monitor energy use of five large appliances (e.g. white appliances, home entertainment systems). The relevant technologies were provided to participants free of charge. Also, they were asked to install an app on their smart phone, tablet, laptop or computer that would provide them with continuous one-hour resolution feedback on the basis of the metering devices installed. Notably, participants received feedback on their total household electricity use, total photovoltaics solar energy production, and energy use of five large appliances measured by individual smart plugs. Participants would receive feedback over a period of two years. More specifically, they received feedback on their energy use and energy production, both real-time as well as about changes in their energy use and energy production during the course of the project.

The metering data would also be used in later stages of the project to study the extent to which participating in the smart energy system would affect households' energy use, to study the effects of various instruments to promote energy savings and to balance energy demand and supply that would be implemented during the course of the project. Furthermore, participants committed themselves to fill out questionnaires on their motivation to participate in, and their experiences with the smart energy system. Hence, participation in the project meant a voluntary two-year long commitment as a research participant, installing smart meters and smart plug devices, using and evaluating a number of energy-related instruments deployed by the project, and giving the research team the right to collect household energy use data for research purposes. Please note that in the current paper we only look at whether participants actually joined the project, we did not test whether they actively participated in the project, for example how often they look at the feedback.

Before the start and announcement of the project, the questionnaire study reported in this paper was conducted among a sample of residents in the targeted neighbourhood. The questionnaire study aimed to study factors influencing whether participants participate in the smart energy system project. Smart energy systems were briefly introduced in the questionnaire as systems that provide users with feedback on one's energy use and energy production on the basis of smart metering data. It was indicated that the feedback aimed to facilitate users to optimally use their own produced solar energy, thereby reducing fossil energy use delivered by large energy companies. Participants could do so by reducing their energy use or by shifting energy use in time as to optimally balance energy demand and supply, or by installing smart appliances that automat-

ically switch on or off depending on the availability of renewable energy.

In late 2012, five research assistants distributed the questionnaires door-to-door among a sample of potential future participants of the project. Approximately 300 people were contacted and asked to fill out the questionnaire. In total 121 questionnaires were recollected at participants' homes upon appointment, of which 9 volunteered to participate in the smart energy system project. Three months later, early 2013, the project was officially introduced, and project-participants were recruited. One hundred households volunteered to participate in the smart energy system project who were all asked to fill out the initial questionnaire as well as soon as they subscribed. It appeared that 82 participants (of the 100 – 9 = 91 participants) who volunteered to participate filled out the questionnaire late 2013. Actual installation of the smart energy system devices started in August 2013.

In total 64 females and 122 males filled out the questionnaire, 17 participants did not indicate their gender. Only one person per household could fill out the questionnaire. Age ranged from 17 to 76 ($M = 46$, $SD = 10.9$). On average the household consisted of three members ($M = 3.3$, $SD = 1.3$) and the majority of participants (90%) was home owner, while 10% rented their house. About 10% of the respondents did not complete any formal education, or completed primary education or vocational secondary school, while 41% had completed the highest level of secondary school or vocational education and 49% finished university. Around 15% of the sample indicated that their monthly net household income was less than 2000 Euros, 55% between 2000 and 4000 Euros, 25% between 4000 and 6000 Euros, while 5% earned more than 6000 Euros per month. Overall, the sample was relatively highly educated and had a higher income than the national average, which is in line with the characteristics of this neighbourhood [4].

2.2. Measures

2.2.1. Values

We used the short value questionnaire to measure biospheric, egoistic, hedonic and altruistic values (see Steg et al. [35]). We measured biospheric values with four items (Respecting the earth: harmony with other species; Unity with nature: fitting into nature; Protecting the environment: preserving nature; Preventing pollution: protecting natural resources). Altruistic values were measured with four items as well (Equality: equal opportunity for all; A world at peace: free of war and conflict; Social justice: correcting injustice, care for the weak; Helpful: working for the welfare of others). Egoistic values were measured with five items (Social power: control over others, dominance; Wealth: material possessions, money; Authority: the right to lead or command; Influential: having an impact on people and events; Ambitious: hardworking, aspiring). Hedonic values were measured with three items (Pleasure: joy, gratification of desires; Enjoying life: enjoying food, sex, leisure etc.; Self-indulgent: doing pleasant things). Participants indicated on a scale from –1 (opposed to my values), 0 (not important) to 7 (extremely important) to what extent the value is important to them as a general goal in their life. The items of the biospheric value scale formed a reliable scale $\alpha = 0.88$ ($M = 4.51$, $SD = 1.31$); the same was true for altruistic values ($\alpha = 0.78$, $M = 4.79$, $SD = 1.15$), egoistic values ($\alpha = 0.79$, $M = 2.31$, $SD = 1.29$), and hedonic values ($\alpha = 0.84$, $M = 4.68$, $SD = 1.35$).

¹ See www.smartgridrendement.nl for more information on the project (in Dutch).

2.2.2. Environmental self-identity

We used an existing and validated scale to measure environmental self-identity: Acting environmentally friendly is an important part of who I am; I am the type of person who acts environmentally friendly; I see myself as an environmentally friendly person [40,41]. Respondents rated each item on a seven point scale, ranging from *totally disagree* to *totally agree*. We computed the mean score on these items, Cronbach's alpha for this scale was 0.93 ($M = 4.29$, $SD = 1.35$).

2.2.3. Problem awareness

Problem awareness was measured with three items measuring the extent to which people are concerned about environmental problems caused by fossil fuels (I worry about CO₂-emissions caused by the use of fossil fuels; Using fossil fuels causes serious environmental problems; The use of fossil fuels is an important cause of climate change). Respondents indicated to what extent they agree with the items on a seven point scale ranging from 1 (totally disagree) to 7 (totally agree). Mean scores were computed ($\alpha = 0.82$; $M = 4.92$, $SD = 1.31$).

2.2.4. Outcome efficacy

Outcome efficacy was measured with three items on a seven point scale (I can contribute to a better environment by using smart energy systems; I can contribute to the reduction of environmental problems by using my own solar energy as much as possible; By using smart energy systems I can contribute to reducing CO₂ emissions). The items formed a reliable scale, Cronbach's alpha is 0.82, therefore mean scores were computed ($M = 5.33$, $SD = 1.15$).

2.2.5. Personal norm

Personal norm to use smart energy systems was measured with three items (I feel morally obliged to use smart energy systems; I would feel guilty if I would not use smart energy systems; I would feel proud if I would use smart energy systems), which were averaged to compute overall scores. Cronbach's alpha was 0.80 ($M = 3.71$, $SD = 1.46$).

2.2.6. Interest in smart energy systems

Interest in smart energy systems was measured with two items (I am interested in smart energy systems; I would like to receive more information on smart energy systems). Participants could answer on a scale from 1 (totally disagree) to 7 (totally agree). Cronbach's alpha is 0.68² ($M = 4.90$, $SD = 1.40$).

2.2.7. Participation in smart energy systems

Furthermore, participants were offered the opportunity to actually participate in the smart energy system. As explained above, participation meant a voluntary two-year long commitment to the project, installing a smart meter and smart plug devices, using and evaluating a number of energy-related instruments deployed by the project, and giving the research team the right to collect household energy use data for research purposes. The devices would help participants monitor their energy use and balance demand and supply which would be done at later stages in the project. Of the 203 participants, 91 volunteered to participate in the smart energy system project (45%).

² As Cronbach's alpha is relatively low, we also tested the models using both items separately as dependent variables. The findings were very similar to the findings reported in the paper where the mean of both items was used as the dependent variable.

2.3. Analyses

We tested the models and the causal pathways between variables with a series of regression analyses and mediation analyses. We calculated bootstrapping confidence intervals for multiple step models to test mediation effects [11]. To compare the predictive power of the VBN theory and the VIP model for the different dependent variables we calculated 95% confidence intervals around the R² values [20,21] (MS-DOS program provided by Steiger and Fouladi [36]). R² values of the regression model are considered to be significantly different when the overlap of these 95% confidence intervals is less than half the distance of one side of the confidence interval (see Masson and Loftus [23]).

3. Results

3.1. VBN theory

We first tested the VBN theory with a series of regression analyses³ (see Table 1). Values explained 12% of the variance in problem awareness. Biospheric and hedonic values were significantly related to problem awareness. The stronger one's biospheric values and the weaker one's hedonic values, the stronger the awareness of environmental problems caused by fossil fuels.

Problem awareness and values explained 42% of the variance in outcome efficacy. The stronger the awareness of problems caused by fossil fuels, the stronger the feelings of outcome efficacy to help reduce these problems. Of the values, only hedonic values were related to outcome efficacy when all variables were included. The stronger one's hedonic values, the weaker outcome efficacy.

Outcome efficacy, problem awareness and values explained 45% of the variance in personal norm. Personal norm to use smart energy systems was stronger the more one felt that environmental problems can be reduced by using smart energy systems and the more one was aware of environmental problems caused by fossil fuels. Hedonic values were negatively related to personal norm when the other variables were controlled for. Thus, the more one cares about comfort and pleasure the less one feels morally obliged to participate in smart energy systems. Altruistic values were marginally significantly and positively related to personal norm.

Personal norm, outcome efficacy, problem awareness and values explained 44% of the variance in interest in smart energy systems, with the 95% confidence interval ranging from 0.30 to 0.53. The stronger one's personal norm to use smart energy systems, the stronger one's interest in smart energy systems. Furthermore, problem awareness positively and significantly predicted interest in smart energy systems: higher problem awareness resulted in a stronger interest in participating in the smart energy system (see Table 1). Outcome efficacy and biospheric values were positively and marginally significantly related to interest in smart energy systems.

A logistic regression revealed that VBN variables explained 21% of the variance in actual participation in the smart energy sys-

³ In addition, we tested and found differences in socio-demographic variables between those who did and those who did not participate in the smart energy systems. Those who participate have a higher income ($M = 4.33$, $SD = 1.42$) compared to those who do not participate ($M = 3.60$, $SD = 1.28$; $t(165) = -3.48$, $p < 0.01$). Participants are also older ($M = 48.66$, $SD = 10.13$) than non-participants ($M = 44.29$, $SD = 11.10$; $t(190) = -2.80$, $p < 0.01$). Participants are higher educated ($M = 5.68$, $SD = 1.11$) than non-participants ($M = 4.80$, $SD = 1.35$; $t(193) = -4.83$, $p < 0.001$). Men are more likely to be a participant than women (83% of the participants is male and 53% of the non-participants; $b = -1.48$, $p < 0.001$) and participants are more likely to own their house than to rent it (96% of the participants own their house, 86% of the non-participants; $b = 1.53$, $p < 0.05$). We did not find any significant differences regarding the age of the house or the number of people in the household.

Table 1
Regression of Participation in Smart Energy Systems on the Value-Belief-Norm Theory.

	β	t	p	Adj. R^2	95% CI R^2	df	F	p
<i>DV: Problem Awareness</i>								
Biospheric values	0.37	4.01	<0.001	0.12	[0.03, 0.20]	172	7.00	<0.001
Altruistic values	0.02	0.20	n.s.					
Egoistic values	−0.01	−0.12	n.s.					
Hedonic values	−0.18	−2.19	0.03					
<i>DV: Outcome efficacy</i>								
Problem awareness	0.59	9.42	<0.001	0.42	[0.29, 0.51]	171	26.18	<0.001
Biospheric values	0.03	0.33	n.s.					
Altruistic values	0.11	1.41	n.s.					
Egoistic values	0.06	0.85	n.s.					
Hedonic values	0.17	2.55	0.01					
<i>DV: Personal norm</i>								
Outcome efficacy	0.41	5.52	<0.001	0.45	[0.32, 0.54]	170	24.87	<0.001
Problem awareness	0.26	3.52	0.001					
Biospheric values	0.06	0.83	n.s.					
Altruistic values	0.14	1.89	0.06					
Egoistic values	0.02	0.39	n.s.					
Hedonic values	−0.18	−2.66	0.01					
<i>DV: Interest in SES</i>								
Personal norm	0.37	4.73	<0.001	0.44	[0.30, 0.53]	168	20.61	<0.001
Outcome efficacy	0.16	1.91	0.06					
Problem awareness	0.20	2.47	0.01					
Biospheric values	0.14	1.80	0.07					
Altruistic values	−0.02	−0.31	n.s.					
Egoistic values	0.04	0.60	n.s.					
Hedonic values	−0.11	−1.56	n.s.					
	b	Wald	p	Nagelkerke's R^2	95% CI R^2	df	χ^2	p
<i>DV: Participation in SES</i>								
Personal norm	0.29	3.22	0.07	0.21	[0.08; 0.29]	7	29.57	<0.001
Outcome efficacy	−0.10	0.23	n.s.					
Problem awareness	0.38	4.18	0.04					
Biospheric values	0.13	0.45	n.s.					
Altruistic values	−0.18	0.74	n.s.					
Egoistic values	0.33	4.54	0.03					
Hedonic values	−0.36	5.32	0.02					

tem, with the 95% confidence interval ranging from 0.08 to 0.29. Personal norm to use smart energy systems was marginally significantly and positively related to participating in the smart energy system project. The more one feels morally obliged to participate the higher the likelihood to participate in smart energy systems. Problem awareness was positively related to actual participation, namely the more one is aware of problems caused by fossil fuels the more likely it is that one will participate. Of all values, only egoistic and hedonic values were significantly related to participation. The stronger one's egoistic values, the more likely it is that one participates in the smart energy system project, while strong hedonic values reduced the likelihood of participating in the smart energy system project.

3.2. Mediation analyses VBN theory

Next, we conducted mediation analysis for the three mediators to further test the causal relationships in the VBN theory [10]. We only included biospheric values in the mediation model as these values were the only values significantly related to variables further down the causal chain of the VBN theory [33]. We found support for the mediation effects as proposed by the VBN theory when interest in smart energy systems was the dependent variable. The mean indirect effect of biospheric values on interest in smart energy systems via problem awareness, outcome efficacy and personal norm was positive and significant ($a_1 \times d_{21} \times d_{32} \times b_3 = 0.03$), with the 95% confidence interval ranging from 0.02 to 0.06. This suggests that the stronger one's biospheric values, the more people are aware of environmental problems caused by fossil fuels,

which leads to stronger feelings that they can contribute to solving these problems by participating in smart energy systems, which in turn relates positively to feelings of moral obligation to participate in smart energy systems, which finally increases their interest in smart energy systems.

We also found support for the mediation effects as proposed in the causal structure of the VBN theory when actual participation in a smart energy system was the dependent variable. The mean indirect effect of biospheric values on participation via problem awareness, outcome efficacy and personal norm was positive and significant ($a_1 \times d_{21} \times d_{32} \times b_3 = 0.03$), the 95% confidence interval ranges from 0.01 to 0.07. This supports the mediation effects in the model when actual behaviour is predicted. Biospheric values strengthen awareness of environmental problems caused by fossil fuels, which strengthens outcome efficacy to solve these environmental problems by participating in smart energy systems. Outcome efficacy in turn strengthens personal norm to participate in smart energy systems, which increases the likelihood that one actually participates in smart energy systems.

3.3. VIP model

Next, we tested the VIP model with a series of regression analyses (see Table 2). Biospheric values explained 23% of the variance in environmental self-identity. The stronger one's biospheric values, the stronger one's environmental self-identity.

Biospheric values and environmental self-identity explained 35% of the variance in personal norm. The stronger one's biospheric

Table 2
Regression of Participation in Smart Energy Systems on the Value-Identity-Personal Norm Model.

	β	t	p	Adj. R^2	95% CI R^2	df	F	p
<i>DV: Environmental self-identity</i>								
Biospheric values	0.48	7.35	<0.001	0.23	[0.13, 0.34]	181	54.06	<0.001
<i>DV: Personal norm</i>								
Environmental self-identity	0.56	8.16	<0.001	0.35	[0.23, 0.46]	180	50.38	<0.001
Biospheric values	0.08	1.23	n.s.					
<i>DV: Interest in SES</i>								
Personal norm	0.45	6.23	<0.001	0.41	[0.29, 0.51]	177	42.51	<0.001
Environmental self-identity	0.22	2.87	<0.01					
Biospheric values	0.08	1.25	n.s.					
	b	Wald	p	Nagelkerke's R^2	95% CI R^2	df	χ^2	p
<i>DV: Participation in SES</i>								
Personal norm	0.44	9.70	<0.01	0.11	[0.03, 0.20]	3	15.28	<0.01
Environmental self-identity	−0.03	0.04	n.s.					
Biospheric values	0.01	0.01	n.s.					

values and the stronger one's environmental self-identity, the more one feels morally obliged to participate in smart energy systems.

The VIP model explained 41% of the variance in interest in smart energy systems, with the confidence interval ranging from 0.29 to 0.51. The stronger one's environmental self-identity and personal norm, the stronger one's interest in smart energy systems.

Finally, the VIP model explained 11% of the variance in actual participation in smart energy systems. The confidence interval ranged from 0.03 to 0.20. The stronger one's biospheric values, the stronger one's environmental self-identity, and the stronger personal norm, the more one is likely to actually participate in smart energy systems.

3.4. Mediation analyses VIP model

We also tested mediation analysis for the VIP model [10]. We found support for the causal structure as proposed by the VIP model when interest in smart energy systems was the dependent variable. The mean indirect effect of biospheric values on interest in smart energy systems via environmental self-identity and personal norm was positive and significant ($a_1 \times d_{21} \times b_2 = 0.13$), with the 95% confidence interval ranging from 0.08 to 0.20. This suggests that the stronger one's biospheric values, the stronger one's environmental self-identity, which leads to stronger feelings of moral obligation to participate in smart energy systems, which influences individuals' interest in smart energy systems.

Finally, we found support for the causal structure proposed in the VIP model when actual participation in a smart energy system was the dependent variable. The mean indirect effect of biospheric values on participation via environmental self-identity and personal norm was positive and significant ($a_1 \times d_{21} \times b_2 = 0.13$), the 95% confidence interval ranges from 0.05 to 0.24. This indicates that biospheric values strengthen one's environmental self-identity, which in turn strengthens the moral obligation to participate in smart energy systems, which promotes the actual participation in smart energy systems.

3.5. Comparison of the VBN theory and VIP model

Our results provide empirical support for both the VBN theory and the VIP model. Both models explained interest in smart energy systems to a similar extent. The VBN theory explained 44% of the variance in interest in smart energy systems with the confidence interval ranging from 0.30 to 0.53. The VIP model explained 41% of the variance in interest in smart energy systems with the confidence interval ranging from 0.29 to 0.51. No significant differences were found in the proportion of variance explained in interest in

smart energy systems, as the confidence intervals overlap considerably.

The VBN theory explained 21% of the variance in actual participation in smart energy systems, while the VIP model explained 11% of the variance. Again, the confidence intervals overlap to a large extent, with the confidence interval of the VBN theory ranging from 0.08 to 0.29, and the confidence interval of the VIP model ranging from 0.03 to 0.20. This implies that the proportion of explained variance in actual participation by the VBN theory and VIP model do not differ significantly, as the confidence intervals overlap more than half the distance of one side of the confidence interval (see Masson and Loftus [23]).

4. Discussion

Our aim was to test which factors influence pro-environmental behaviour in an important new domain, namely participation in smart energy systems. Smart energy systems optimize the use of locally produced renewable energy thereby reducing the use of fossil fuels. We compared the predictive power of the value-belief-norm theory to a novel model, the values-identity-personal norm model. Both models focus on normative considerations however, the VIP model is more parsimonious than the VBN theory and focuses on general predictors of environmental behaviour. The causal relationships between the variables as proposed in both models were confirmed. We did not find significant differences in the predictive power of both models, suggesting both predicted interest in smart energy systems and actual participation in smart energy systems to a similar extent.

Even though the VIP model focuses mostly on general predictors and is more parsimonious than the VBN model they explain the interest and actual participation to a similar extent. This is interesting from a practical point of view, as general factors are related to a range of pro-environmental behaviours [39]. Therefore, policies focusing on these general factors may promote a range of pro-environmental behaviours at once. By activating one's biospheric values or by strengthening environmental self-identity many pro-environmental actions may be stimulated. Indeed, research suggests that environmental self-identity may be an important factor promoting positive spill-over to other pro-environmental behaviours. Future research is needed to test if positive spill-over is indeed more likely when focusing on the VIP model compared to the VBN theory. In addition to the practical implication this finding is also interesting from a research perspective. When testing the VIP model many behaviours can be studied at once, as only the personal norm items need to be adapted to the specific behaviours. Studies testing the VBN theory generally adapt

awareness of consequences and outcome efficacy to the specific behaviours as well and therefore need to include many variables. Our findings thus show that both models predict interest and participation in smart energy systems to a similar extent, but the VIP model is more parsimonious and can be more easily applied to predict other behaviours as well. Therefore, the VIP model may be more promising when aiming to promote a range of pro-environmental actions or when studying a range of environmental behaviours. Future research is needed to test the generalizability of our findings by testing how well the VBN theory and the VIP model predict environmental behaviour in other domains.

Interestingly, the general variables in the models (namely values and environmental self-identity) were related to the dependent variables when the specific variables of the model were included in the analyses as well. Biospheric values predicted interest in smart energy systems, while hedonic and egoistic values predicted actual participation in smart energy systems when all other variables of the VBN theory were included as well. In the VIP model, environmental self-identity still predicted interest in smart energy systems when the other variables of the model were included as well. However, biospheric values and environmental self-identity were no longer related to actual participation in smart energy systems when personal norm was included as well. Our results show that general predictors of behaviour are not only important because they can predict a wide range of environmental behaviours, but also because they predict environmental behaviour when more specific factors are included in the model as well. Although the behaviour specific factors generally predicted the dependent variables more strongly, the general factors still played a role. This again suggests that environmental policies that target these general factors, for example by strengthening environmental self-identity or by strengthening, supporting, or activating biospheric values, may motivate people to engage in a range of environmental behaviours.

In addition to previous studies testing the VBN theory, we also included hedonic values in our analyses. People with strong hedonic values focus on comfort and pleasure in their lives [35]. We found that these values predict the dependent variables. More specifically, the stronger one's hedonic values, the less likely it is that someone is aware of environmental problems caused by the use of fossil fuels, the more strongly one feels that participating in smart energy systems will reduce these problems, and the less one feels morally obliged to participate in smart energy systems. We did not find a relationship between hedonic values and interest in smart energy systems when the other variables were included in the analysis. However, we did find that hedonic values influenced actual participation in smart energy systems when all other variables of the VBN theory were included in the analysis. The results show that people who strongly endorse hedonic values are less likely to participate in smart energy systems, perhaps because they anticipate that actually participating in a smart energy system involves a reduction in one's comfort. In smart energy systems participants are often stimulated to shift energy consumption to times when renewable energy is available, for example, when the sun is shining or when the wind is blowing. It was explained to participants of the current project that participants would be asked to shift their energy consumption to times when renewable energy is available. Changing times of energy consumption may be effortful or reduce comfort [6], which may particularly be a barrier for people with strong hedonic values. As many environmentally-friendly behaviours, such as reducing energy consumption, switching modes of transport, may involve a reduction of comfort hedonic values may be an important factor to include when studying environmental behaviour, particularly when these behaviours may reduce comfort.

Our results show that participation in smart energy systems is explained by normative considerations as proposed by the VBN the-

ory and the VIP model. The more people care about these normative considerations the more interested they are in smart energy systems and the more likely it is that they will actually participate in smart energy systems. However, actual participation was to a lesser extent explained by the normative considerations than interest in smart energy systems. This is in line with the suggestion by Stern [37] that the VBN theory less strongly predicts effortful or costly behaviour, as well as previous research showing that costly behaviour (such as actual participation) is explained less by normative consideration than less costly behaviour or intentions [17]. When it concerns the more costly actual participation other considerations such as concerns about effort and comfort seem to become important as well, reflected by the influence of egoistic and hedonic values on actual participation. However, in our study we did not measure how difficult people found participating in the smart energy system. Future research should address this by measuring perceived effort or comfort of shifting energy use in time. In the current study we tested if people joined the two year project, which meant a voluntary two-year long commitment as a research participant, installing smart meters and smart plug devices, using and evaluating a number of energy-related instruments deployed by the project, and giving the research team the right to collect household energy use data for research purposes. However, we did not test to what extent they actively participated in the project, for example by testing to what extent they used their smart plug devices. Future research should test whether the VBN theory and the VIP model also influence the extent to which participants actively participate in the project. Furthermore, future research studying actual participation in smart energy systems should test whether our findings can be replicated and include factors related to the costs or comfort as well.

Our study has important practical implications. The findings suggest that when one aims to reduce environmental problems by increasing the use of smart energy systems it is important to focus on the benefits for the environment of smart energy systems. The more important people find these consequences, the more likely it is that they will participate. Furthermore, by focusing on general predictors such as biospheric values or environmental self-identity not only participation in smart energy systems, but a range of pro-environmental behaviours may be promoted. This could be done by stressing which other pro-environmental actions people already conduct (thereby strengthening environmental self-identity; [42]) and by stressing the environmental benefits of participating in smart energy systems thereby linking the behaviour to one's biospheric values. However, when it concerns actual participation it is also important to address factors relating to effort and comfort considerations. For example, by trying to reduce comfort losses caused by smart energy systems as much as possible. Smart technologies that automatically turn on appliances when renewable energy is available may increase participation in smart energy systems as well as this may reduce comfort loss. By doing so the participation in smart energy systems may be increased, thereby reducing environmental problems.

Acknowledgements

We would like to thank Marko Milovanovic for the data collection. This paper was made possible by the TaskForceInnovation project: Smart Grids, value for all. See: www.smartgridrenedement.nl.

References

- [1] I. Ajzen, in: P.M. Gollwitzer, J.A. Bargh (Eds.), *The Directive Influence of Attitudes on Behavior*, Guilford Press, New York, NY, US, 1996, pp. 385–403.

- [2] L. Andersson, S. Shivarajan, G. Blau, Enacting ecological sustainability in the MNC: a test of an adapted value-belief-norm framework, *J. Bus. Ethics* 59 (3) (2005) 295–305.
- [3] J. Beyea, The smart electricity grid and scientific research, *Science* 328 (5981) (2010) 979–980.
- [4] CBS, Statistics Netherlands Statline, 2015, Retrieved from: <http://statline.cbs.nl/> (accessed 29.06.16).
- [5] Eurostat, Final Energy Consumption by Sector, 2014, Retrieved from: <http://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-5/assessment> (accessed 29.06.16).
- [6] M.J. Fell, D. Shipworth, G.M. Huebner, C.A. Elwell, Public acceptability of domestic demand-side response in Great Britain: the role of automation and direct load control, *Energy Res. Soc. Sci.* 9 (2015) 72–84.
- [7] F. Fornara, P. Pattitoni, M. Mura, E. Strazzera, Predicting intention to improve household energy efficiency: the role of value-belief-norm theory, normative and informational influence, and specific attitude, *J. Environ. Psychol.* 45 (2016) 1–10.
- [8] B. Gatersleben, N. Murtagh, W. Abrahamse, Values, identity and pro-environmental behaviour, *Contemp. Soc. Sci.: J. Acad. Soc. Sci.* 9 (4) (2012) 374–392.
- [9] M. Goulden, B. Bedwell, S. Rennick-Egglestone, T. Rodden, A. Spence, Smart grids, smart users? The role of the user in demand side management, *Energy Res. Soc. Sci.* 2 (2014) 21–29.
- [10] A.F. Hayes, Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-based Approach, Guilford Press, 2013.
- [11] A.F. Hayes, K.J. Preacher, T.A. Myers, Mediation and the estimation of indirect effects in political communication research, in: E.P. Bucy, R.L. Holbert (Eds.), *Sourcebook for Political Communication Research: Methods, Measures, and Analytical Techniques*, Routledge, New York, 2010.
- [12] R. Hledik, How green is the smart grid? *Electr. J.* 22 (3) (2009) 29–41.
- [13] IPCC, in: Core Writing Team, R.K. Pachauri, L.A. Meyer (Eds.), *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, IPCC, Geneva, Switzerland, 2014, 151 pp.
- [14] A. Jakovcovic, L. Steg, Sustainable transportation in Argentina: values, beliefs, norms and car use reduction, *Transp. Res. Part F: Traffic Psychol. Behav.* 20 (2013) 70–79.
- [15] J. Jansson, A. Marell, A. Nordlund, Exploring consumer adoption of a high involvement eco-innovation using value-belief-norm theory, *J. Consum. Behav.* 10 (1) (2011) 51–60.
- [16] F.G. Kaiser, G. Hübner, F.X. Bogner, Contrasting the theory of planned behavior with the value-belief-norm model in explaining conservation behavior, *J. Appl. Soc. Psychol.* 35 (10) (2005) 2150–2170.
- [17] M. Keizer, L. Steg, M. Van Zomeren, The role of normative considerations in over-all and short-distance car use in seven European countries submitted for publication (2016) submitted for publication.
- [18] C.B. Kobus, E.A. Klaassen, R. Mugge, J.P. Schoormans, A real-life assessment on the effect of smart appliances for shifting households' electricity demand, *Appl. Energy* 147 (2015) 335–343.
- [19] C.B.A. Kobus, R. Mugge, J.P.L. Schoormans, Washing when the sun is shining! How users interact with a household energy management system, *Ergonomics* 56 (3) (2013) 451–462, <http://dx.doi.org/10.1080/00140139.2012.721522>.
- [20] Y. Lee, Tables of the upper percentage points of the multiple correlation coefficient, *Biometrika* 59 (1972) 179–189.
- [21] Y.S. Lee, Some results on the sampling distribution of the multiple correlation coefficient, *J. R. Stat. Soc. B* 33 (1971) 117–130.
- [22] H.B. Lind, T. Nordfjærn, S.H. Jørgensen, T. Rundmo, The value-belief-norm theory: personal norms and sustainable travel mode choice in urban areas, *J. Environ. Psychol.* 44 (2015) 119–125.
- [23] M.E.J. Masson, G.R. Loftus, Using confidence intervals for graphically based data interpretation, *Can. J. Exp. Psychol.* 57 (3) (2003) 203–220.
- [24] V.G. Morwitz, J.H. Steckel, A. Gupta, When do purchase intentions predict sales? *Int. J. Forecast.* 23 (3) (2007) 347–364.
- [25] A.M. Nordlund, J. Garvill, Value structures behind pro-environmental behavior, *Environ. Behav.* 34 (2002) 740–756.
- [26] E. Oldfield, Addressing energy poverty through smarter technology, *Bull. Sci. Technol. Soc.* 31 (2) (2011) 113–122.
- [27] S. Oreg, T. Katz-Gerro, Predicting proenvironmental behavior cross-nationally: values, the theory of planned behavior, and value-belief-norm theory, *Environ. Behav.* 38 (4) (2006) 462–483, <http://dx.doi.org/10.1177/0013916505286012>.
- [28] A. Ruepert, K. Keizer, L. Steg, F. Maricchiolo, G. Carrus, A. Dumitru, D. Moza, Environmental considerations in the organizational context: a pathway to pro-environmental behaviour at work, *Energy Res. Soc. Sci.* 17 (2016) 59–70.
- [29] B.H. Sheppard, J. Hartwick, P.R. Warshaw, The theory of reasoned action: a meta-analysis of past research with recommendations for modifications and future research, *J. Consum. Res.* (1988) 325–343.
- [30] N.D. Sintov, P.W. Schultz, Unlocking the potential of smart grid technologies with behavioral science, *Front. Psychol.* 6 (2015) 410.
- [31] M.W. Slimak, T. Dietz, Personal values, beliefs, and ecological risk perception, *Risk Anal.* 26 (6) (2006) 1689–1705.
- [32] L. Steg, J.I.M. De Groot, L. Dreijerink, W. Abrahamse, F. Siero, General antecedents of personal norms, policy acceptability, and intentions: the role of values, worldviews, and environmental concern, *Soc. Nat. Resour.* 24 (4) (2011) 349–367.
- [33] L. Steg, L. Dreijerink, W. Abrahamse, Factors influencing the acceptability of energy policies: a test of VBN theory, *J. Environ. Psychol.* 25 (4) (2005) 415–425.
- [34] L. Steg, G. Perlaviciute, E. van der Werff, Understanding the human dimensions of a sustainable energy transition, *Front. Psychol.* 6 (2015) 1–17.
- [35] L. Steg, G. Perlaviciute, E. Van der Werff, J. Lurvink, The significance of hedonic values for environmentally-relevant attitudes, preferences, and actions, *Environ. Behav.* 46 (2) (2014) 163–192.
- [36] J.H. Steiger, R.T. Fouladi, R2: a computer program for interval estimation, power calculations, sample size estimation, and hypothesis testing in multiple regression, *Behav. Res. Methods* 24 (1992) 581–582.
- [37] P.C. Stern, Toward a coherent theory of environmentally significant behavior, *J. Soc. Issues* 56 (3) (2000) 407–424.
- [38] P.C. Stern, T. Dietz, T. Abel, G.A. Guagnano, L. Kalof, A value-belief-norm theory of support for social movements: the case of environmentalism, *Human Ecol. Rev.* 6 (2) (1999) 81.
- [39] E. Van der Werff, L. Steg, One model to predict them all: predicting energy behaviours with the norm activation model, *Energy Res. Soc. Sci.* 6 (2015) 8–14, <http://dx.doi.org/10.1016/j.erss.2014.11.002>.
- [40] E. Van der Werff, L. Steg, K. Keizer, The value of environmental self-identity: the relationship between biospheric values, environmental self-identity and pro-environmental preferences, intentions and behaviour, *J. Environ. Psychol.* 34 (2013) 55–63, <http://dx.doi.org/10.1016/j.jenvp.2012.12.006>.
- [41] E. Van der Werff, L. Steg, K. Keizer, It is a moral issue: the relationship between environmental self-identity, obligation-based intrinsic motivation and pro-environmental behaviour, *Global Environ. Change* 23 (2013) 1258–1265, <http://dx.doi.org/10.1016/j.gloenvcha.2013.07.018>.
- [42] E. Van der Werff, L. Steg, K. Keizer, I am what I am, by looking past the present the influence of biospheric values and past behavior on environmental self-identity, *Environ. Behav.* 46 (5) (2014) 626–657.
- [43] G.P.J. Verbong, S. Beemsterboer, F. Sengers, Smart grids or smart users? Involving users in developing a low carbon electricity economy, *Energy Policy* 52 (2013) 117–125.
- [44] J.C. Whitehead, T.L. Cherry, Willingness to pay for a green energy program: a comparison of ex-ante and ex-post hypothetical bias mitigation approaches, *Resour. Energy Econ.* 29 (4) (2007) 247–261, <http://dx.doi.org/10.1016/j.reseneeco.2006.10.001>.
- [45] M. Wolsink, The research agenda on social acceptance of distributed generation in smart grids: renewable as common pool resources, *Renew. Sustain. Energy Rev.* 16 (2012) 822–835.